Rapid Hydrographic, Optical and Microstructure Surveys on the Continental Shelf and Slope

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LONG-TERM GOALS

To understand the dynamics of mesoscale circulation over the continental shelf and slope, with an emphasis on fronts, jets, eddies and topographic influences. To examine the relationship between circulation processes and the spatial distributions of mixing and optical properties over the continental margin.

OBJECTIVES

To investigate the relationship between mesoscale circulation and spatial distributions of mixing and optical properties over the continental shelf and slope. To understand how lateral variations in the density, velocity, mixing and optical fields influence variations in vertical mixing processes observed at a single mid-shelf location. Specific objectives of this project are: to determine the characteristics and spatial scales of mixing and optical properties on the continental shelf and slope in the Middle Atlantic Bight south of Marthas Vineyard; to investigate how distributions of mixing and optical properties depend on characteristics of the mesoscale coastal circulation; to describe how the characteristics and distributions of mixing and optical properties on the shelf differ between seasons and relate these differences to seasonal contrasts in coastal circulation and water-column structure.

APPROACH

As part of the Coastal Mixing and Optics (CMO) Accelerated Research Initiative, we made contemporaneous measurements of density, light absorption/attenuation and microstructure using sensors mounted on SeaSoar, a towed undulating measurement platform. The SeaSoar sensor suite includes a dual-sensor Sea-Bird CTD, a nine-wavelength spectral absorption and attenuation meter (WET Labs ac9) and a new microstructure instrument (MicroSoar). Horizontal velocity is measured using a 300-kHz shipboard acoustic Dopper current profiler (ADCP). We conducted rapid surveys using R/V Endeavor during two 21-day field experiments in the Middle Atlantic Bight centered near 40.5N, 70.5W, south of Marthas Vineyard. We completed a summer survey, when the shelf is stratified, from 14-Aug to 1-Sep 1996 and a spring survey, when the shelf water tends to be more mixed, from 25-Apr to 15-May 1997. During each field experiment we collected data from repeated large-region surveys over a roughly 70 x 80 km box completed in about 2 days. Alternating with the large-region surveys, measurements were concentrated in a small box (roughly 25 x 25 km completed in 14 hours) centered around a mid-shelf location where the physical and optical fields were intensively sampled by our CMO colleagues using moored instrumentation and vertical profiling from a stationary ship.

The co-PIs on this project are J. Barth and P. M. Kosro. A Faculty Research Assistant, R. O'Malley, is responsible for CTD data processing and data report production. A Postdoctoral Research Associate, D. Bogucki, is working part-time with J. Barth to process and analyze the extensive optical data set. Another Research Associate, Steve Pierce, is working with P. M. Kosro to process and analyze the shipboard ADCP data set. T. Dillon is leading the effort to process and analyze the MicroSoar data, together with help from a Faculty Research Assistant, Dr. Anatoli Erofeev.

WORK COMPLETED

During this first analysis year of the CMO ARI, we have processed data collected during two 21-day cruises in summer 1996 and spring 1997, analyzed in detail several facets of the shelf and slope mesoscale circulation, presented preliminary results at the 1998 Ocean Sciences Meeting and begun collaborations with other CMO PIs. We have processed data from the instruments aboard SeaSoar, with which we made approximately 34,900 vertical profiles of the water column over the continental shelf and slope during the CMO cruises, and from the shipboard ADCP. Hydrographic fields obtained from the CTD onboard SeaSoar have been reported in O'Malley et al. (1998), an online version of which can be found at http://diana.oce.orst.edu/cmoweb/csr/main.html.

Velocity data from the ADCP was processed using bottom tracking, DGPS ship's navigation and high-quality ship's heading from the R/V Endeavor's TANS system, and was reported in Pierce et al. (1998), online at http://diana.oce.orst.edu/cmoweb/adcp/main.html. Velocity data from our two 21-day CMO cruises together with moored velocity data from Levine and Boyd (SAS PRIMER, Jul-Sep 1996), Pickart (Shelfbreak PRIMER, Dec 1995 to Feb 1997), and Beardsley and Gawarkiewicz (Shelfbreak PRIMER, Jul-Aug 1996) have been used to estimate barotropic tidal currents in the CMO region. An empirical method following Candela et al. (1992) was used with bilinear polynomial spatial functions for M2 and K1, and zero-order functions for S2, N2 and O1. From the empirical tidal velocity model, the M2 contains 75% of the tidal variance and K1 another 9%. The M2 semi-major axis varies from 0.02 m/s over the slope to 0.30 m/s at the northeast corner of the CMO region. Ellipses tend to be nearly circular, especially near the CMO central site (40.5N, 70.5W). Comparisons with historical estimates for the region (Moody et al., 1984) showed plus or minus 0.02 m/s rms difference in M2 overall. The barotropic tidal prediction is used to produce subtidal velocity fields from the measured shipboard ADCP velocities, revealing the details of the frontal jets and eddies over the shelf and slope. An investigation of the internal tide in this region using the empirical model technique is underway.

Analysis and evaluation of data from the new microstructure instrument (MicroSoar) flown aboard SeaSoar continues. Data from the fast-response capillary microconductivity probe sampling at 2 kHz, from adjacent temperature and pressure sensors, and from a three-axis accelerometer have been processed. Details of the MicroSoar design have been published (May, 1997) and a paper describing the MicroSoar system and the techniques for obtaining fields of temperature variance dissipation rate (chi), Cox number and heat flux has been submitted (Dillon et al., 1998). Finally, the entire CMO MicroSoar data set, including vertical sections and horizontal maps of microstructure properties, has been reported in Erofeev et al. (1998), online at http://diana.oce.orst.edu/cmoweb/micro/main.html.

Processing of optical data from the nine-wavelength absorption and attenuation meter (WETLabs ac-9) flown aboard SeaSoar has required new processing techniques. As reported in Barth and Bogucki (1998), it is critical to calculate a time-dependent lag between when the optical properties were measured and when the CTD sensors sampled the same water parcel so that the optical data can be corrected for known dependence on temperature (and to a lesser extent on salinity) (Pegau and Zaneveld, 1994). Processing of the voluminous spectral absorption and attenuation data set is nearing completion with results to be reported in an OSU data report. Preliminary vertical sections of some optical properties from the August 1996 cruise are available online at http://diana.oce.orst.edu/cmoweb/ac9/main.html.

RESULTS

Time-dependent maps of the three-dimensional distributions of hydrographic, velocity and optical properties over the shelf and slope in the Middle Atlantic Bight south of Cape Cod show the importance of advection and mesoscale (with horizontal dimensions of the size of the Rossby radius) and sub-mesoscale structure on vertical structure at a mid-shelf location. Examples, reported in previous ONR Annual Reports and at the 1998 Ocean Sciences Meeting, include intrusions from offshore of warm, salty and relatively clear slope water at both the bottom and near the surface, mesoscale meanders reaching shoreward from the shelfbreak front and jet, and packets of internal solitary waves propagating onshore with attendant significant displacement of the thermocline and deep chlorphyll maximum at the base of the pycnocline. The spring 1997 cruise captured the restratification of the water column and an anomalous shoreward extent of a warm, salty bottom boundary layer driven by eastward near-bottom flow likely associated with a backward-breaking unstable meander of the shelfbreak front and jet.

Evidence for secondary circulation associated with a shelfbreak front was obtained from a high-resolution, cross-shelf section of hydrographic, optical and velocity fields (Figures 1 and 2). Convergence in the bottom boundary layer on the inshore side of the front and subsequent upwelling into the interior is evident by a mid-water region of suspended bottom material emanating from the foot of the front (40.35N, 85-m isobath) and extending to within 35 m of the surface, 80 m above bottom. Downwelling on the offshore side of the front in the upper water column is inferred from a 20-m downward bend of the subsurface phytoplankton layer. Between approximately 35 and 50m, the two maxima, chlorophyll offshore and suspended bottom material inshore, are separated horizontally and have different optical properties as shown by the spectra in Figure 2. These observations are in agreement with recent model predictions for secondary circulation near an idealized shelfbreak front (Gawarkiewicz and Chapman, 1992; Chapman and Lentz, 1994). Convergence in measured cross-shelf velocity at the foot of the front is consistent with upwelling of bottom material detected there. An estimate of 9 plus or minus 2 m/day of upwelling on the inshore side of the shelfbreak front is obtained, implying a transit time from the bottom to the surface of 10-16 days. Complimentary evidence for convergence near the foot of the shelfbreak front and subsequent upwelling was found by Houghton and Visbeck (1998) using a purposeful dye release in the BBL. They estimate an equivalent upwelling velocity of 4-7 m/day, consistent with results presented here. This secondary circulation has important implications for the biogeochemistry of shelfbreak fronts through upwelling of nutrients into the euphotic zone and concentration of material on the offshore side of the front.

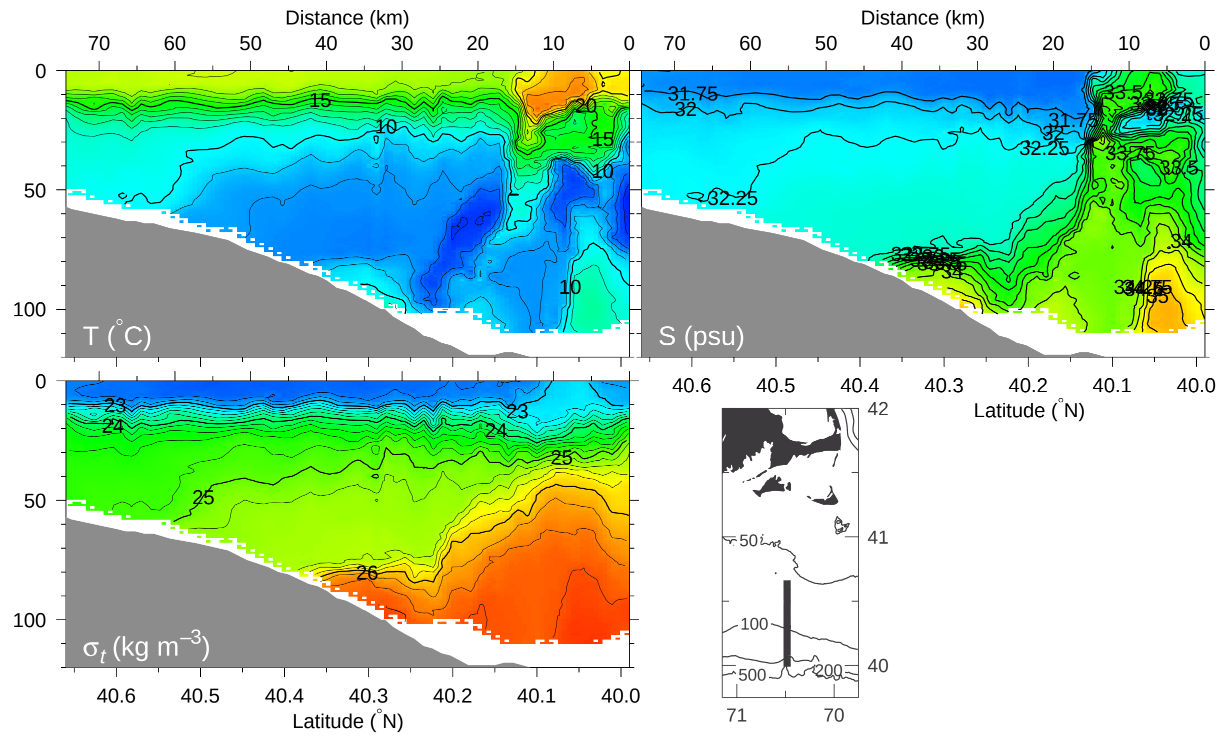

Figure 1. Cross-shelf sections of temperature, salinity and density along 70.48W from 13:01 to 19:35 UTC on August 21, 1996. The location of the cross-shelf section is indicated by a thick line on the map.

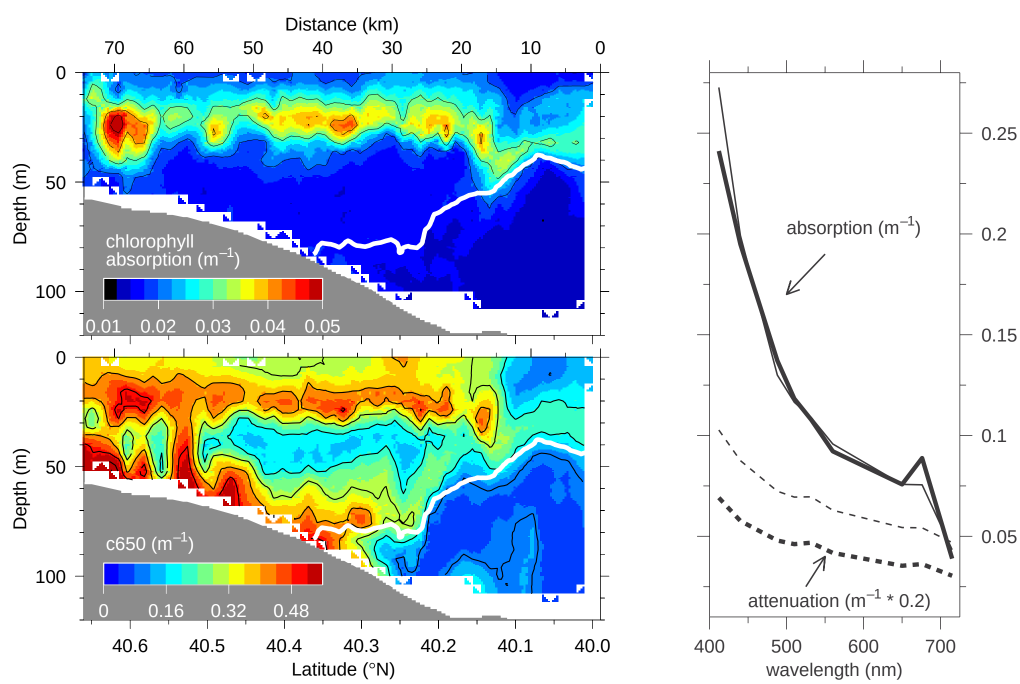

Figure 2. Cross-shelf sections of chlorophyll absorption and 650-nm light attenuation measured with a nine-wavelength absorption and attenuation instrument on the towed, undulating vehicle SeaSoar along 70.48W from 13:01 to 19:35 UTC on August 21, 1996. The thick white curve is the sigma-t=25.8 kg/m**3 isopycnal. On the right are spectra of light absorption (solid curves) and attenuation (dashed curves) from a depth of 50 m at 40.13N (thick curves) and at 40.21N (thin curves).

IMPACT/APPLICATIONS

By combining the simultaneous measurement of hydrography, velocity, optical properties and fine-scale temperature variance from over the continental margin, we expect to make progress understanding the dynamics of the interactions between these fields. Understanding processes will lead to a greater predictive capability for specifying the physical and optical property distributions and their time-dependent behavior over the continental margin.

TRANSITIONS

The MicroSoar technology is being packaged for use by Ron Zaneveld on his optical profiling package and for Dave Hebert (URI) for use during the GLOBEC cross-frontal fluxes study on Georges Bank. The MODAPS+ data acquisition and power supply system is being used by other groups (T. Cowles, OSU; C. Roesler, UConn) and is available from WETLabs for use by other interested parties. Our SeaSoar and shipboard ADCP data sets are available for use by CMO colleagues. The Optical Oceanography group at OSU (Zaneveld, Pegau, Barnard) is using our surface Seasoar optical data from spring 1997 to verify their algorithms for obtaining absorption properties from satellite ocean color sensors.

RELATED PROJECTS

We will collaborate with our CMO colleagues who are using moored instrumentation and vertical profiling from a stationary ship to address the goals of the ARI. The overall success of the program relies on being able to separate local mixing dynamics and their effects on optical property distributions from advective effects influenced by mesoscale coastal circulation. We also plan to work with scientists participating in the ONR "Synthetic Aperture Sonar" PRIMER and in the Shelfbreak PRIMER, both of which were conducted near the CMO central site.

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